Technical Demand Priorities for Sustainable Development of Soybean Production in China: An Analysis of On-site Survey

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Abstract: A national wide on-site survey was conducted to identify the main constraints of soybean production and the priorities for technical demands of stakeholders in Chinese soybean industry. The limiting factors for soybean production and the corresponding technical demands were analyzed from 3 major soybean producing regions in China, including the Northern Spring Soybean Region, Yellow-Huai-Hai Rivers Valley Summer Soybean Region, and Southern Multi-cropping Soybean Region. In addition, the technical demand priorities were identified in 6 research fields. Based on the constrains of soybean production and the technical demands, we concluded that the future R & D of soybean industry in China should focus on developing high-yielding varieties; improving the techniques of cultivation, fertilization, and integrated weed control; applying sowing, harvesting and tillage machinery associated with the cultivation techniques; using soybean enzyme engineering techniques in soybean processing; and taking measures to reduce soybean production costs. Further, the region-specific strategy should be developed to address the issues of local soybean industry development.

Key words: China; Soybean industry; Constraints; Technical demand; Priority

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中国大豆产业技术需求分析

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摘要: 为了解中国大豆产业的技术需求,有针对性地开展科学研究,国家大豆产业技术体系于2008、2009和2010年,采用问卷调查方式对北方春大豆区、黄淮海流域夏大豆区和南方多作大豆区共22个省(市、区)的2 787个大豆产业技术用户进行了技术需求调查,将技术需求划分为大豆新品种、栽培与土壤肥料技术、病虫草害防控技术、农业机械

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及使用技术、产后处理与加工技术和市场信息服务 6 个研究领域,并明确了各领域技术发展的优先序,将高产大豆新品种培育,大豆栽培和施肥技术,大豆田难除杂草综合防治技术,适合各地条件的播种、收获、耕整地机械,大豆酶工程技术和降低大豆生产成本的措施列为优先研究方向。在采用参与式评估方法分析各主产区生产限制因素的基础上,提出了促进中国大豆产业发展的措施。

关键词:中国;大豆产业;限制因素;技术需求;优先序

As the largest soybean producing country and exporter in the history, China is known as the home of the soybean. However, since the mid-1990s, the supply and demand of soybean in China have dramatically changed. Soybean import exceeded export in the country due to the increased demands for soybean oil and soybean meal in 1996[1]. Now, China is the leading importer of soybean and ranks fourth in soybean production worldwide. In 2012, China imported 58.38 million tons of soybean[2], and the self-sufficiency percentage decreased to approximately 18.27%[3]. In 2013, the importation soared to 63.38 million tons[4]. In contrast, the soybean production in China increased slowly. Comparing the data of three-year average from 1996 to 1998, the planting area, production, and yield of soybean only increased by −3.45%, −0.94% and 2.07% from 2010 to 2012, respectively[3,5]. This stagnant soybean production and increased importation lead to wide concern regarding the future of soybean industry in China[6-10]. Thus, measures to control these deteriorating conditions must be taken. A variety of researches have explored the factors that affect the development of Chinese soybean industry. Continuous attention has been given to the following issues: comparative advantages and international competitiveness[7,11-12], industry safety[13], risk assessment and management[14-18], genetic modified soybean[19-21], production efficiency[22-23], and the development strategy[24-25] of the soybean industry in China. However, little investigation has been conducted regarding the development orientation of soybean technology[26].

China witnessed a top-down rather than bottom-up technology development system[27]. However, conventional 'technology transfer' strategies of R & D do not work well in complex environments[28]. In addition, a great deal of work was undertaken by adopting participatory and problem-oriented approaches. In these approaches, the farmer's role in agricultural production was stressed[29-33]. Awareness regarding the critical roles of farmers in agricultural production continues to increase. To facilitate the ability of technology research to address the technical demands of soybean farmers, the National Soybean Industry Technology Research and Development Center organized an in-depth technical demand survey of the soybean industry in 2008, 2009 and 2010.

1 Materials and methods

In 2008, 2009 and 2010, questionnaires were distributed to the following subjects: Ministry of agriculture departments (bureaus and stations), agricultural administrative departments in major soybean-producing provinces and autonomous regions, state farm systems, China Soybean Industry Association members, specialized farmers' cooperatives, large-and small-scale soybean growers, seed suppliers, soybean processors, chambers of commerce, and academic organizations in 22 provinces (autonomous regions and municipalities). Overall, 102 soybean experts in the National Soybean Industry Technology System participated in the data collection and assessment. Data of 2 787 respondents from 3 major soybean producing regions[34], i. e. the Northern Spring Soybean (mainly the Northeast China), Yellow-Huai-Hai Rivers Valley Summer Soybean, and Southern China Multi-cropping Soybean regions, were consolidated in the analysis. Among these respondents, 1 849 were soybean growers, and 938 were experts, technicians, or agricultural administrators, which accounted for 66.3% and 33.7% of the total participants, respectively. The constraints of Chinese soybean industry and the technical demand priorities of the farmers were identified. And the technical demands were classified into the 6 following fields: better varieties, farming management and fertilization techniques, plant protection techniques, agricultural mechanization techniques, post-harvest treatment and processing techniques, and market information services.

All statistical analysis was conducted with IBM SPSS Statistics 19.0 software[35].

2 Results and analysis

2.1 The constraints of soybean production in different regions

2.1.1 Northern Spring Soybean region The follow-

ing constraints occur in the Northern Spring Soybean Region:(1) The high and stable yielding varieties with high disease resistance, oil content, and protein contents are sparse. (2) Planting and management techniques are lacking. (3) The scale of soybean planting on farms is small. (4) The existing varieties cannot adapt to a wide range of environmental conditions. (5) The field infrastructure and tolerance of the crops to natural disasters are poor. (6) Continuous cropping results in serious pest and disease problems. (7) Tillage techniques are poor and large-scale machinery is not available for small farmers. Those factors result in thin topsoil and a hard plow pan that limits soybean growth. (8) Fertilizer misuse and a lack of organic fertilizers decrease the soil organic matter. (9) The price of soybeans is low, the market is limited, and soybean farmers' actual income is decreasing. In some cases, this income is nearly equal to the production cost. Thus, the unstable income of soybean farmers further leads to fluctuations in soybean planting acreage and yield.

2.1.2 Yellow-Huai-Hai Rivers Valley Summer Soybean region The following constraints occur in this region:(1) Government support to soybean production is insufficient. Furthermore, technical services are not demand-oriented, and the production technology specification is not well established. (2) The adoption rates of the new varieties are low. (3) The soybean farmers are not active in soybean growing.

2.1.3 Southern China Multi-cropping Soybean region The following constraints occur in the Southern China Multi-cropping Soybean region:(1) R & D investment is insufficient. (2) Soybean genetic resources are not fully exploited, and the soybean yield is low. Many local varieties are available, but the varieties suitable for intercropping are scarce. And the coverage of high quality varieties is small. (3) Soybean pests and diseases are serious. (4) Cost-saving soybean planting techniques are insufficient. (5) Alternating drought and flooding stress lead to poor yield performances. (6) Soil is unfertile. (7) The cropping fields are fragmented, and field management is extensive. (8) The level of agricultural mechanization is low due to the small production scale and the hilly terrain.

2.2 Priority order of the technical demands from different technical fields of the Chinese soybean industry

The technical demands from different fields of the Chinese soybean industry are summarized and divided into six aspects after the statistical and priority analysis.

2.2.1 Demand priority for the better varieties In total, 1 394 respondents indicated a technical demand for the better varieties, which fell into ten different categories. The demand priority for the better varieties was as follows: High-yielding varieties > Stress-tolerant varieties > Disease and pest-resistant varieties > High-protein varieties > Shade-tolerant and lodging resistant varieties > Selection and management techniques of varieties > High-oil varieties > Special purpose varieties > Breeding method > Biotech varieties (Table 1). The demand for high-yielding varieties was highest and was indicated by up to 49.14% of the respondents in this field. The result demonstrated that soybean yield could potentially be improved. Because the production cost is relatively high and the potential for increasing the number of acres planted is limited, yield increase is the best way to improve the benefits of planting soybean. The demands for stress-tolerant and disease-and pest-resistant varieties were ranked second and third, respectively. Thus, farmers urgently need stress tolerant varieties to resist unfavorable environmental factors.

Table 1 Demand priority for the better varieties in China

Priority order	Variety type or technique	Number of respondents with technical demand	Percentage of total respondents/%
1	High-yielding varieties	685	49.14
2	Stress-tolerant varieties	257	18.44
3	Disease-and pest-resistant varieties	192	13.77
4	High-protein varieties	84	6.03
5	Shade-tolerant and lodging resistant varieties	74	5.31
6	Selection and management techniques of varieties	48	3.44

Continuing Table 1

Priority order	Variety type or technique	Number of respondents with technical demand	Percentage of total respondents/%
7	High-oil varieties	28	2.01
8	Special purpose varieties	20	1.43
9	Breeding methods	5	0.36
10	Biotech varieties	1	0.07
	Total	1394	100.00

2.2.2 Technical demand priority for farming management and fertilization The technical demand priority for farming management and fertilization, as shown in Table 2, was as follows: Cultivation techniques > Fertilizing techniques > Plant nutrition management techniques > Tillage techniques > Soil improvement techniques > Standard specifications > Water saving irrigation techniques > High yield formation theory. Cultivation techniques were the highest demand, which indicated that assorted high yield techniques were necessary other than improved varieties to reach the goal of yield and benefit enhancement. Fertilizing techniques were ranked second, indicating that farmers have realized the importance of scientific fertilizer application. In this case, soil testing for fertilizer recommendations should be promoted to optimize the use of the applied fertilizer.

Table 2 **Technical demand priority for farming management and fertilization in China**

Priority	Technical demand	Number of respondents with technical demand	Percentage of total respondents/%
1	Cultivation techniques	546	54.60
2	Fertilizing techniques	247	24.70
3	Plant nutrition management techniques	73	7.30
4	Tillage techniques	50	5.00
5	Soil improvement techniques	39	3.90
6	Standard specifications	30	3.00
7	Water-saving irrigation techniques	13	1.30
8	High yield formation theory	2	0.20
	Total	1000	100.00

2.2.3 Technical demand priority for plant protection In the field of plant protection, the technical demand priority was as follows: Integrated weed control techniques > Diagnosis, identification, prevention and control techniques for *phytophthora sojae* and other soil-borne diseases > Control methods for soybean pod borer (*Leguminivora Glycinivorella* (Mats.)) > Prevention and control techniques for soybean aphid (*Aphis glycines*) > Detection, prevention and control techniques for soybean stem and foliar diseases > Diagnosis, prevention, and control techniques for soybean mosaic virus > Chemical application techniques > Prevention and control techniques for grub (*Holotrichia diomphalia Bates*), soybean stem-miner (*Melanagromyza sojae* (Zehntner)), eriococcus (*Ericoccus* sp.), and other underground pests > Prevention and control techniques for soybean cyst nematode (*Heterodera glycines* Ichinohe) > Prevention and control techniques for carmine spider mite (*Tetranychus cinnabrinus* (Boisduval)) > Mitigation techniques for the disadvantages of continuous soybean cropping > Techniques for herbicide phytotoxicity removal > Prevention and control techniques for soybean parasitic seed plants > Prevention and control techniques for other leaf-feeding insect pests (Table 3). The integrated weed control techniques were the highest demand, which indicated that weed had become one of the greatest problems for soybean production.

Table 3 Technical demand priority for plant protection of soybean production in China

Priority order	Technical demand	Number of respondents with technical demand	Percentage of total respondents/%
1	Integrated weed control techniques	198	14.98
2	Diagnosis, identification, prevention and control techniques for *phytophthora sojae* and other soil-borne diseases	151	11.42
3	Control methods for soybean pod borer(*Leguminivora glycinivorella*(Mats.))	121	9.15
4	Prevention and control techniques for soybean aphid(*Aphis glycines*)	105	7.94
5	Detection, prevention and control techniques for soybean stem and foliar diseases	102	7.72
6	Diagnosis, prevention, and control techniques for soybean mosaic virus	101	7.64
7	Chemical application techniques	90	6.81
8	Prevention and control techniques for grub(*Holotrichia diomphalia Bates*), soybean stem-miner(*Melanagromyza sojae*(Zehntner)), eriococcus (*Ericoccus* sp.) and other underground pests	88	6.66
9	Prevention and control techniques for soybean cyst nematode (*Heterodera glycines* Ichinohe)	82	6.20
10	Prevention and control techniques for carmine spider mite (*Tetranychus cinnabrinus*(Boisduval))	59	4.46
11	Mitigation techniques for the disadvantages of continuous soybean cropping	45	3.40
12	Techniques for herbicide phytotoxicity removal	29	2.19
13	Prevention and control techniques for soybean parasitic seed plants	9	0.68
14	Prevention and control techniques for other leaf-feeding insect pests	142	10.74
	Total	1322	100.00

2.2.4 Technical demand priority for agricultural mechanization The technical demand priority for the field of agricultural mechanization, as shown in Table 4, was as follows: Sowing machinery > Harvesting machinery > Tillage machinery > Irrigation and water conservancy facilities > Cultivating and plant protection machinery > Accessory protective cultivation machinery > Seed processing equipment > Key technique and equipment for variable rate operations in precision agriculture > Stalk reusing equipment. In practice, farmers sow too many seeds, which increases the cost of seeds. Further, over seeding will result in weak individual plants. And, the population tends to lodge, which results in a lower yield. Thus, crop yield may be enhanced by improving the seeding quality and by promoting precision drilling technology. Consequently, the technical demand for sowing machinery was the highest among the demands to agricultural mechanization. In addition, machinery used for harvesting results in production losses of up to 5%. Furthermore, field works were increasingly performed by females and aged individuals, which lead to an urgent need for labor savings harvesting machinery. Thus, the technical demand for harvesting machinery was ranked second.

Table 4 Technical demand priority for agricultural mechanization of soybean production in China

Priority order	Technical demand	Number of respondents with technical demand	Percentage of total respondents/%
1	Sowing machinery	144	23.11
2	Harvesting machinery	135	21.67
3	Tillage machinery	123	19.74
4	Irrigation and water conservancy facilities	89	14.29
5	Cultivating and plant protection machinery	74	11.88
6	Accessory protective cultivation machinery	26	4.17
7	Seed processing equipment	15	2.41

Continuing Table 4

Priority order	Technical demand	Number of respondents with technical demand	Percentage of total respondents/%
8	Key technique and equipment for variable rate operations in precision agriculture	11	1.77
9	Stalk reusing equipment	6	0.96
	Total	623	100.00

2.2.5 The technical demand priority for post-harvest treatment and processing The demand priority for the post-harvest treatment and processing fields, as shown in Table 5, was as follows: Enzyme engineering techniques > Soybean protein engineering techniques > Fermentation engineering techniques > Membrane separation techniques > Modern separation techniques > Traditional soybean food processing techniques > Microencapsulation techniques > Extrusion and expanding techniques > Genetic engineering techniques > High-frequency electric field techniques > Superfine comminution techniques > High-pressure processing techniques. The current investigation indicated that the production of traditional and modern soybean products required modern technology. In addition, more technical demand was focused on enzyme, protein and fermentation engineering techniques. Genetic engineering, high-frequency electric field, superfine comminution techniques, and high-pressure processing techniques were not urgently needed because they required further research and heavy investment.

Table 5 **Technical demand priority for post-harvest treatment and processing of soybeans in China**

Priority order	Technical demand	Number of respondents with technical demand	Percentage of total respondents/%
1	Enzyme engineering techniques	27	25.71
2	Soybean protein engineering techniques	26	24.76
3	Fermentation engineering techniques	19	18.10
4	Membrane separation techniques	14	13.33
5	Modern separation techniques	8	7.62
6	Traditional soybean food processing techniques	3	2.86
7	Microencapsulation techniques	2	1.90
8	Extrusion and expanding techniques	2	1.90
9	Genetic engineering techniques	1	0.95
10	High-frequency electric field techniques	1	0.95
11	Superfine comminution techniques	1	0.95
12	High-pressure processing techniques	1	0.95
	Total	105	100.00

2.2.6 Demand priority for market information services Regarding market information services, the demand priority was as follows: Measures or policies to reduce production costs > Market information > Price protection > Large-scale production > Early warning system (Table 6). Currently, soybean production costs in China are relatively high, and the comparative profits are relatively low. Thus, reducing production costs was the primary concern in this field. In addition, market information was stressed here, which indicated that the small households had trouble accessing market information. Price protection was ranked third, indicating that farmers need help from the government to maintain a relatively reasonable pricing system and to ensure the benefits of growing soybean.

Table 6 Demand priority for market information services in soybean industry of China

Priority order	Demand	Number of respondents with technical demand	Percentage of total respondents/%
1	Measures or policies to reduce production costs	43	43.88
2	Market information	19	19.39
3	Price protection	17	17.35
4	Large-scale production	15	15.30
5	Early warning system	4	4.08
	Total	98	100.00

2.2.7 Comparison of technical demands between the different regions of China The region-specific technical demands priorities, as shown in Table 7, were as follows:

Northern Spring Soybean region: Better varieties > Farming management and fertilization techniques > Plant protection techniques > Agricultural mechanization techniques > Post-harvest treatment and processing techniques > Market information services.

Yellow-Huai-Hai Rivers Valley Summer Soybean region: Better varieties > Plant protection techniques > Farming management and fertilization techniques > Agricultural mechanization techniques > Market information services > Post-harvest treatment and processing techniques

Southern Multi-cropping Soybean region: Better varieties > Farming management and fertilization techniques > Plant protection techniques > Agricultural mechanization techniques > Market information services > Post-harvest treatment and processing techniques.

Table 7 Technical demand priority of different fields in the different regions of China

Survey region	Priority order	Technical demand field	Number of respondents with technical demands	Percentage of total respondents/%
Northern Spring Soybean region	1	Better varieties	449	29.40
	2	Farming management and fertilization	414	27.11
	3	Plant protection	344	22.53
	4	Agricultural mechanization	231	15.13
	5	Post-harvest treatment and processing	46	3.01
	6	Market information services	43	2.82
		Total	1527	100.00
Yellow-	1	Better varieties	506	38.48
Huai-Hai Rivers Valley Summer	2	Plant protection	354	26.92
Soybean region	3	Farming management and fertilization	309	23.50
	4	Agricultural mechanization	103	7.83
	5	Market information services	37	2.81
	6	Post-harvest treatment and processing	6	0.46
		Total	1315	100.00
Southern Multi-	1	Better varieties	356	53.29
cropping Soybean region	2	Farming management and fertilization	138	20.66
	3	Plant protection	109	16.32
	4	Agricultural mechanization	44	6.59
	5	Market information services	14	2.10
	6	Post-harvest treatment and processing	7	1.05
		Total	668	100.00
Nation-wide	1	Better varieties	1394	36.87
	2	Plant protection	1322	24.80

Continuing Table 7

Survey region	Priority order	Technical demand field	Number of respondents with technical demands	Percentage of total respondents/%
	3	Farming management and fertilization	1000	22.98
	4	Agricultural mechanization	623	10.86
	5	Market information services	105	2.69
	6	Post-harvest treatment and processing	98	1.79
		Total	4542	100.00

3 Discussion

Researchers have consistently appealed to the society to identify key scientific questions and to help determine innovative research topics that aim to solve practical problems. The current investigation responds to this need. This study contains the first across-the-board survey regarding the technical demands of the Chinese soybean industry. Here, the stakeholders' technical demands for soybean production are fully stressed. Results from the main constraints of soybean production in China and the technical demands in different fields will help researchers organize their research based on regional expertise and crop distribution. And the government will take it for reference to outline the development strategy of soybean industry.

The technical demand for better varieties was ranked as the top concern in the three main soybean production regions in China. Furthermore, this demand increased from the North to the South. These results showed that farmers understood the importance of soybean varieties for increasing productivity. The demand for the high yield, high quality, stress-tolerant, and widely adapted varieties was growing rapidly, especially for the high yield varieties that were suitable for local intercropping in South China. In the Northern Spring Soybean and Southern Multi-cropping Soybean regions, the technical demand for farming management and fertilization was higher than that of field plant protection. These results differ from those of the Yellow-Huai-Hai Rivers Valley Summer Soybean region. Thus, high yield cultivation techniques, which were made for the high quality varieties, were urgently needed in the Northern Spring Soybean and Southern Multi-cropping Soybean regions. In addition, plant protection was the primary concern in the Yellow-Huai-Hai Rivers Valley Summer Soybean Region.

In response to the technical demands in different research fields, which were clarified in this survey, the following specific technology development strategies were proposed.

Breeding elite varieties High yield varieties with disease and pest resistance, stress tolerance and lodging resistance are urgently needed in all three soybean producing regions in China. Furthermore, high protein, oil or special purpose varieties are needed. The demand for better varieties increases from the North to the South in China. Presently, the average soybean yield in China is much lower than that of other major crops, and other soybean producing countries. Thus, yield improvement will generate more profit for soybean growers.

Previously, it was suggested that high yield was the most important requirement in this field. However, the immerging trend is to improve the comprehensive characteristics of new varieties. Yang *et al.* compared the key soybean yield limiting factors from 18 and 20 provinces (autonomous regions) of China in 2010 and 2011, respectively. These authors found that the key limiting yield component for soybeans was the number of seeds per plant in Northeast and South China. Furthermore, plant density was the most limiting factor in the Northwest and in the Yellow-Huai-Hai Rivers Valley regions[36]. Therefore, measures to improve soybean yield performances should be regionally oriented. In addition to high yields, the high quality and multi-resistant traits are necessary. The dominant local varieties should be developed and popularized. Updated varieties should be promoted, and large scale planting should be encouraged to fully improve yield potential[37].

Soybean produced in the Northeast China were mainly for oil processing before. Since the huge amount of high oil soybean importation and increasing demand to domestic soybean for food purpose in recent years, the high protein soybean varieties are firstly needed in the Northeast China.

Adopting region specific farm management and fertilization techniques The yield potential of good varieties cannot be determined without considering the corresponding planting techniques[38]. However, different as-

pects will be stressed in different planting regions.

Northern Spring Soybean region: Generally, soil moisture is insufficient and the air temperature is low in Northeast China during the spring. Thus, during the soybean-growing season, this area is prone to arid conditions and early frost. In addition, the soil quality is deteriorating, and the disease, pest, and weed control is difficult. Furthermore, the soybean production cost is high, and the production margin is low in this region. Thus, yield and quality should be increased, the cost should be reduced, and an effective and sustainable production technology system including rotation, deep chisel tillage, and direct seeding should be established.

Yellow-Huai-Hai Rivers Valley Summer Soybean region: This region features a short soybean-growing season between two winter wheat crops, infertile soils, and uneven precipitation. The quality of soybean sowing is poor, and the diseases, pests and weeds are serious in this region. Furthermore, the fertilizer application is irrational, and a standard planting system is absent. Thus, a high yield, highly effective and standard production technology system should be set up by integrating post-winter wheat no-till seeding technologies, reasonable planting densities, balancing fertilization and integrated pest management.

Southern Multi-cropping Soybean region: Standard and labor saving soybean production technology patterns should be established by integrating intercropping and multiple cropping, minimal tillage and no tillage, *rhizobium* inoculation, drought and waterlog relief, and disease, pest, and weed control techniques. Because of the low yield and poor quality of soybean in this region, high yield, high quality, and high stress resistance varieties are needed. Furthermore, highly effective vegetable soybean production techniques are necessary as well. The soybean/energy crops (sugarcane, cassava, etc.) intercropping and wheat/corn/soybean intercropping models should be developed to maximize favorable growing conditions and to obtain high and stable yields.

In addition, soil testing for fertilizer recommendation should be promoted, and organic fertilizers should be used. In this way, the soybean farmers can benefit from reduced production costs and increased soybean yield. Furthermore, the soil structure may improve, and the rotation practices can result in sustainable land use.

Taking comprehensive plant protection measures The major technical demands to plant protection techniques in China include integrated weed control techniques; the diagnosis, identification, prevention and control techniques for *phytophthora sojae* and other soil-borne diseases; and methods for controlling the soybean pod borer (*Leguminivora glycinivorella* (Mats.)).

Basic research regarding weed growth and reproduction in soybean fields should be emphasized to determine effective countermeasures. In addition, we can consider to adopt the herbicide tolerant biotech soybean to deal with weed control in farming systems, like that in the US, Brazil, and Argentina. Regarding the disease and pest control, safe and environment friendly pesticides should be developed. Furthermore, a forecasting system based on GIS and Internet technologies should be established to exchange information to make precautionary decisions.

Elevating agricultural mechanization levels Major technical demands to agricultural mechanization include the techniques and equipment for sowing, harvesting and tillage. These technical demands aim to improve seeding quality, fertilization precision and operational efficiency, and to reduce soil and fertilizer loss. The agricultural irrigation systems must also be improved due to the frequent occurrence of natural disasters. Simultaneously, plant protection and seed processing equipment are in high demand. In the Northern Spring Soybean region, especially in the state owned farms where large scale planting is dominant, the demand for modern machinery takes first priority. In the Southern Multi-cropping Soybean region, small machinery that can cater to soybean production in small areas is required. The mechanization level and the standardization level should be improved in all soybean-producing areas to enhance labor efficiency and reduce production costs. Furthermore, agricultural infrastructure construction should be strengthened to improve the ecological environment and to achieve sustainable development of the soybean industry.

Post-harvest treatment and processing technologies It is important to boost the use of enzyme engineering, soybean protein engineering, fermentation engineering, and membrane separation techniques and other techniques that involve processing traditional soybean products, new soybean products and functional soybean foods. Furthermore, it is important to improve the construction of scientific, large-scale, standardized, automatic and commercialized soybean food production systems, and to improve soybean product detection and quality control systems.

Market information services and policies The cost-

savings problem attracted widespread attention. The soaring price of labor, fertilizer and herbicide has resulted in high production costs. Researchers should address responsive mechanisms that will help farmers formulate profitable production portfolios at various scales. In response to this requirement, the government should increase its high quality seed subsidies to cover all soybean-planting areas. In addition, the cost-saving technology should be promoted to reduce production costs, enhance the comparative benefit of soybean production, and stimulate the involvement of soybean farmers[37].

4 Conclusions

In the first nation wide survey targeting at the technical demand of soybean farmers in China, it clarified the major binding constraints of soybean production in three major producing regions. They share the common concerns, such as the lack of better varieties and the planting techniques specification, but the regional differences are obvious.

It identified the technical demand priorities of the farmers for soybean production according to technical demand fields and soybean production regions. The results indicated that the future R&D of soybean industry in China should focus on developing high-yielding varieties; improving the techniques of cultivation, fertilization, and integrated weed management; applying sowing, harvesting and tillage machinery associated with the cultivation techniques; using soybean enzyme engineering techniques in soybean processing; and taking measures to reduce soybean production costs. The technical demand for better varieties was ranked as the top concern in the three main soybean production regions in China. Furthermore, this demand increased from the North to the South. In the Northern Spring Soybean and Southern Multi-cropping Soybean regions, the technical demand for farming management and fertilization was higher than that of plant protection, but the Yellow-Huai-Hai Rivers Valley Summer Soybean region showed the reverse condition. This survey filled the knowledge gap between the researchers and other stakeholders of soybean industry. The future development strategy of soybean industry should be regional specific and demand-oriented considering the apparent regional difference of development constrains and the divergent technical demand priorities.

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